

A new map of the vegetation of Burundi

An extension of the potential natural vegetation map of eastern Africa

Paulo van Breugel^{1,2} & Roeland Kindt²

1. Forest, Nature and Biomass, Department of Geosciences and Management of Natural Resources, Copenhagen University, Rolighedsvej 23, 1958 Frederiksberg C, Denmark; 2. World Agroforestry Centre, P.O. Box 30677-00100, Nairobi, Kenya; 3. Natural History

Introduction

The major change in version 2.0 of the potential natural vegetation map of eastern Africa (<http://vegetationmap4africa.org>) was the addition of a new map of the potential natural vegetation of Burundi. Below the steps are explained which were used to create the potential natural vegetation map for Burundi. The main baseline map selected for Burundi was Pouilloux

1979 (Figure 1), which was georeferenced and digitized by the geospatial laboratory at the World Agroforestry Centre (ICRAF).

Other baseline maps included historical soil maps (Van Wambeke 1957) and maps of vegetation belts in western Burundi (Lewalle 1972; Figure 2). A number of classification criteria were developed based on a comparison with vegetation boundaries of the VECEA map, consultation with national botanical and ecological experts from Burundi, and literature sources, including Lewalle 1972; Reekmans 1981; Masharabu 2011; Pouilloux 1979; White 1983 and the report on biodiversity strategies for Burundi prepared by the Institut National pour l'Environnement et la Conservation de la Nature (INECN) in 2000. These criteria were used to convert the above-mentioned baseline maps into a potential natural vegetation map. The description of these criteria

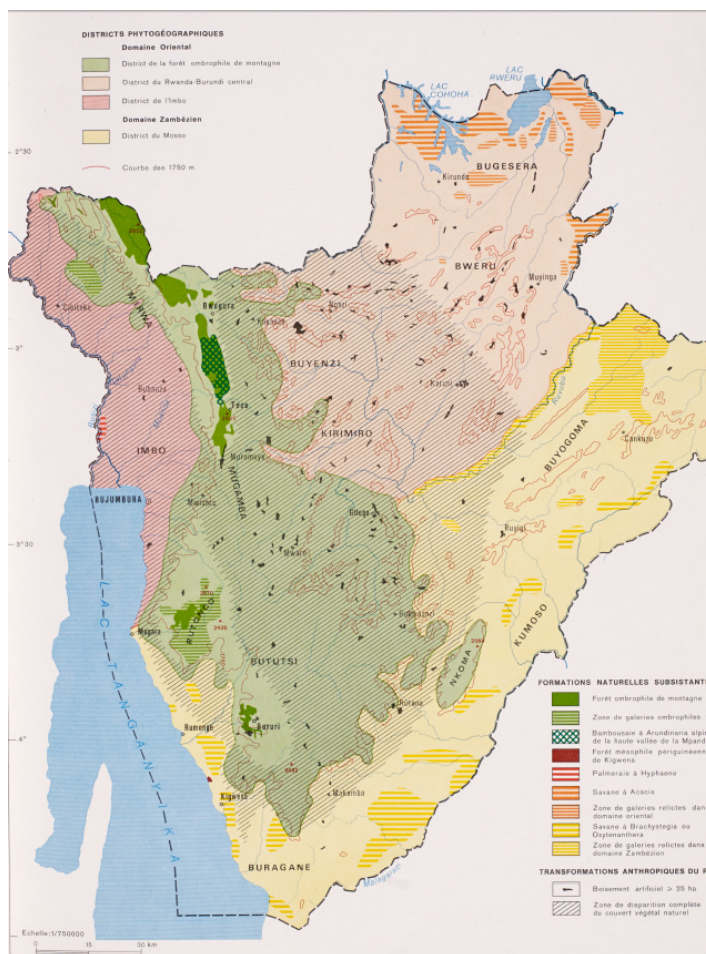


Figure 1: The vegetation map developed by Pouilloux for the Atlas of Burundi (1979).

and the methods used to implement them are described below. Note that the description is in the order in which the different steps were implemented.

Methods

Base line data

The baseline data used to create the map is the Atlas du Burundi (Pouilloux 1979; Figure 1). Some mapping units of this map were translated directly into their respective PNVs, while others could not be simply translated into the respective PNV. Instead, a number of mapping units are assumed to contain more than one PNV. Criteria and methods used to split these mapping units are explained in the following sections.

For creation of altitudinal zones, used to (re)classify a number of PNVs, we used the SRTM 90m Digital Elevation [Database v4.1](#) as input (name of this layer in the code below is 'dem').

Assign unique identifiers to vegetation units

First step was to import the digitized map in the GRASS GIS database as veg_burundi. The attribute table of that map with names and identifiers are given in Table 1. Next, in the vector attribute table, we assigned a unique numerical identifier to each unique vegetation/land use type, using the SQL update function (example code below). The vector map was subsequently converted to raster layer with a resolution of 3 arc seconds.

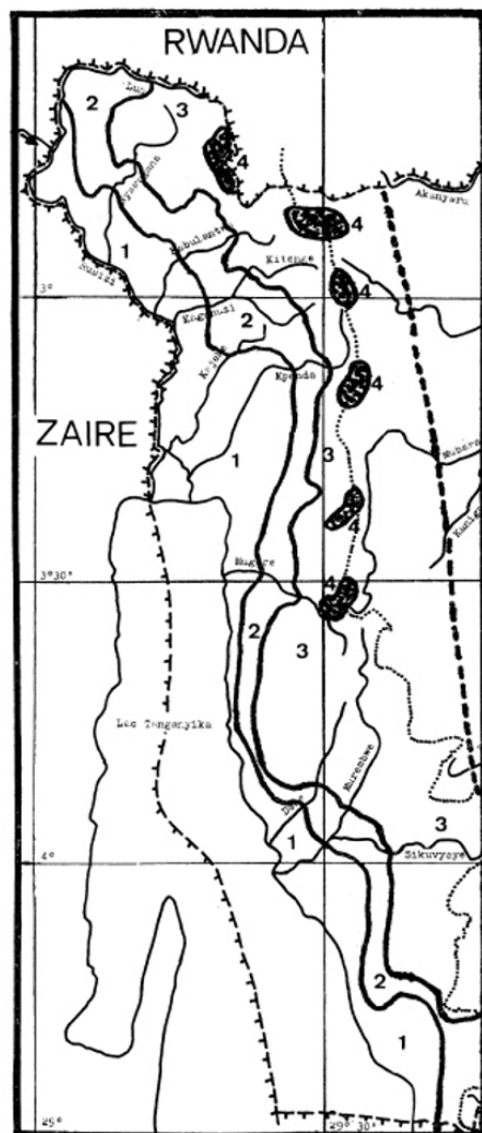


Figure 2. Vegetation map of Burundi (Lewalle 1972, page 151- 152). The four zones correspond to 1) l'etage inferieur, de 780 a 1000 m environ, correspondant a l'Imbo; subdivise en une partie septentrionale (northern) et une partie meridionale (southern); 2) l'etage de transition, de 1000 a 1600 m environ, correspon-dant au Mumigwa; 3) l'tage montagnard, de 1600 a 2400 m environ, correspon-dant au Bufundu-Mugamba et au Bututsi; 4) l'etage afro-subalpin, au-dessus de 2400 m, correspondant a quelques sommets inclus dans le Bufundu-Mugamba.

Create Fa, Ff and E

The mapped distribution of the forêt ombrophile de montagne is assumed to represent Afromontane rain forest (Fa), whereas the district de la forêt ombrophile is assumed to represent the Lake Victoria transitional rainforest (Ff).

1. Lake Victoria transitional rainforest (Ff): 1600 – 1900 m
2. Afromontane rain forest (Fa): 1900 m - 2450 m, but not in the Arundinaria alpine bamboo zone

The altitudinal zones cover areas larger than the corresponding areas on the Pouilloux map (Figure 3). In both cases we opted to use the altitudinal zones. In addition, vegetation type 4 on the Lewalle map (1972; Figure 2) was assumed to represent the Montane Ericaceous belt. In Rwanda we did not map the Ericaceous belt separately, except in the Virunga Mountains.

To ensure consistency in the classification, we created a mask (Figure 4) covering the high altitude areas in Burundi and the border areas in Rwanda and classified all areas above 2450m as Ericaceous Belt (B).

Figure 3. Montane zones overlaid with A) 1600-1900m altitude zone and B) > 1900 m altitude zone

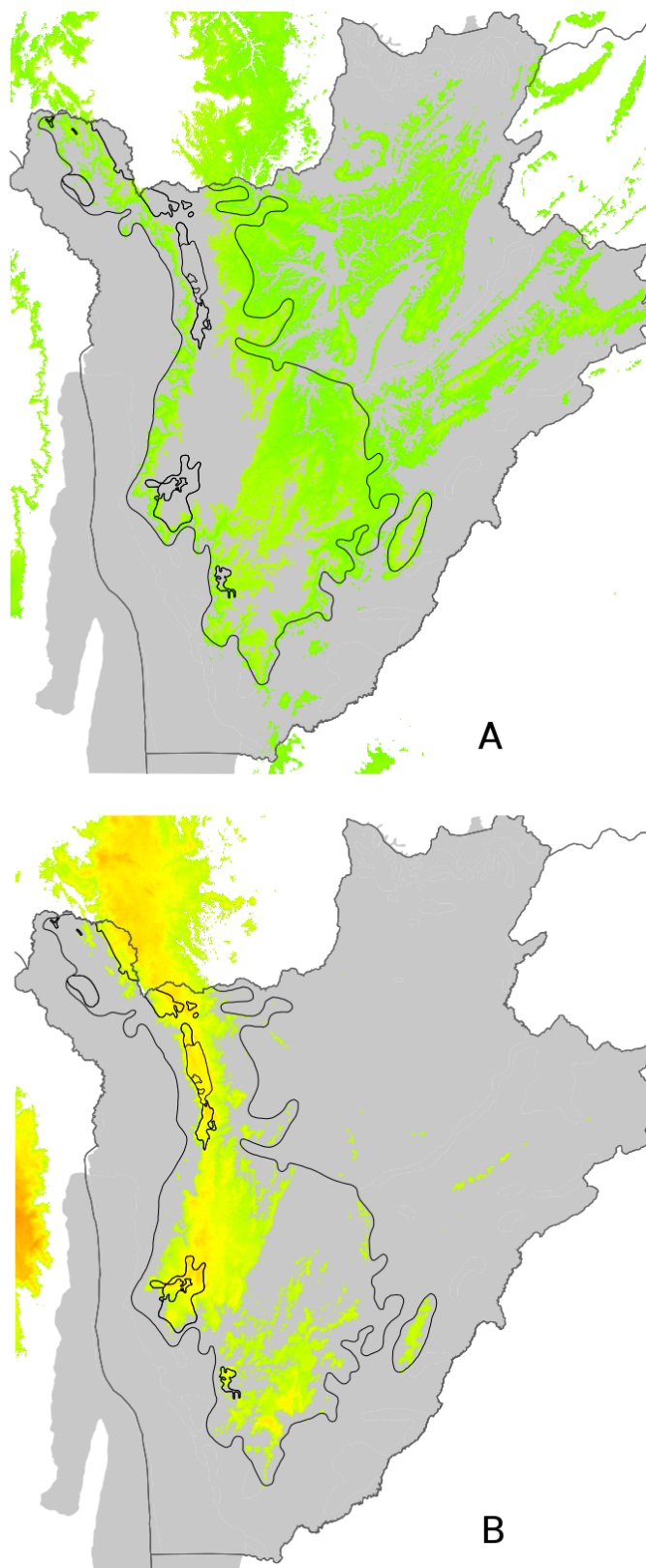


Table 1. The numerical identifier assigned to each of the vegetation units in the veg_burundi vector map.

VegID	Vegetation types
1	Acacia wooded grassland
2	Afromontane bamboo (arundinaria alpina) in the mpanda valley
3	District de l'imbo _ imbo zone
4	District de la forêt ombrophile de montagne _ montane forest zone
5	District du mosso _ mosso zone
6	District du rwanda _ burundi central _ central rwanda_burundi zone
7	Hyphaene palm wooded grassland
8	Lake tanganyika
9	Miombo (brachystegia) or lowland bamboo (oxytenanthera) wooded grassland
10	Montane forest
11	Montane forest relicts
12	Periginean intermediate forest
13	Subzone in the zambezian domain with riverine forest relicts
14	Subzone in the eastern domain with riverine forest relicts

```
# Create temporary mask including highlands in Burundi
# and border area Rwanda, and create layer identifying
# Ericaceous Belt

v.to.rast input=EricaceousMaskRwanda@BurundiVegetation
output=EricaceousMaskRwanda use=val
r.mask raster=EricaceousMaskRwanda --overwrite
r.mapcalc "map1 = if(dem@PERMANENT>2450,36,null())" --overwrite

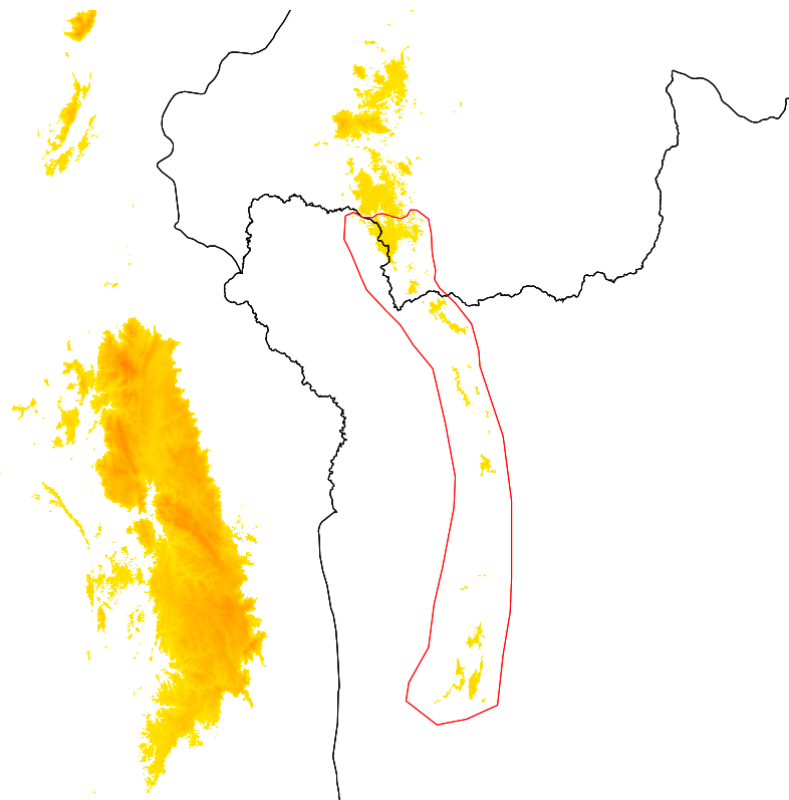
# Create new mask covering Burundi and the areas
# classified as Ericaceous Belt on Rwanda

r.mask -r
v.extract input=Afr_adm0@PERMANENT where="NAME_ISO = 'BURUNDI'"
output=Burundi
v.to.rast input=Burundi output=Burundi use=val --overwrite
r.patch input=Burundi,map1 output=mask_pnv_burundi --overwrite

# Set the new mask and compute the Fa and Ff

r.mask raster=mask_pnv_burundi@BurundiVegetation
r.mapcalc "map1 = if(dem@PERMANENT>2450,36,
if(dem@PERMANENT>1900,1,if(dem@PERMANENT>1600,7,-9999)))" -overwrite
```

Create mosaic of Lake Victoria Euphorbia dawei scrub forest (fe) and Lake Victoria Strychnos potatorum scrub forest (Ft)



All area in the *Imbo district* below 1600 m were mapped as a mosaic of Lake Victoria Euphorbia dawei scrub forest (fe) and Lake Victoria Strychnos potatorum scrub forest (Ft). The latter is a PNV not yet defined for the VECEA region. Note that this zone overlaps (roughly) with the transitional rain forest (gridcode 4) and evergreen bushland (gridcode 45) on the White map.

Figure 4. The mask (red outline) within which all areas with altitudes > 2450m were classified as Ericaceous Belt.

```
# Concert the veg_burundi vector layer to a raster layer
# and define the fe/Ft

v.to.rast input=veg_burundi@BurundiVegetation output=veg_burundi use=attr
attrcolumn=VegID --overwrite
r.null map=veg_burundi null=-9999
r.mapcalc "map2 = if(veg_burundi==3 & dem@PERMANENT<=1600, 97, map1)"
--overwrite
```

Mosaic of Evergreen and semi-evergreen bushland and thicket (Be) and upland Acacia wooded grassland (We)

The two vegetation types Evergreen and semi-evergreen bushland and thicket (Be) and upland Acacia wooded grassland (We) were mapped as a mosaic in the *District Rwanda-Burundi*, below 1600 m.

```
r.mapcalc "map3 = if(veg_burundi==6 & dem@PERMANENT<=1600, 98, map2)"
--overwrite
```

Miombo woodland (Wm)

The areas in 'District du Mosso' phytogeographic region below 1600 m is reclassified as Wetter miombo woodland (Wmw)

```
r.mapcalc "map4 =if(veg_burundi==5 & dem@PERMANENT<=1600, 57, map3)"
```

Wetter miombo woodland with lowland Bamboo

The type *Miombo (Brachystegia) or lowland Bamboo (Oxytenanthera) wooded grassland* was reclassified as a mosaic of wetter miombo woodland and lowland bamboo

```
r.mapcalc "map5 =if(veg_burundi==9, 99, map4)" --overwrite
```

Lake Victoria drier peripheral semi-evergreen Guineo-Congolian rain forest (Fi)

Forêt mésophile périguinéenne de Kigwena (Periginean intermediate forest) was assumed to be the Lake Victoria drier peripheral semi-evergreen Guineo-Congolian rain forest (Fi)

```
r.mapcalc "map6 =if(veg_burundi==12, 10, map5)" --overwrite
```

Palm wooded grassland (P)

The polygon of *Hyphaene palm* in the Imbo district was reclassified as Palm wooded grassland (P)

```
r.mapcalc "map7 =if(veg_burundi==7, 39, map6)" --overwrite
```

Afromontane bamboo

The *Bambousaie à Arundinaria alpine de la haute vallée de la Mpanda* was reclassified as Afromontane bamboo

```
r.mapcalc "map8 =if(veg_burundi==2, 35, map7)" --overwrite
```

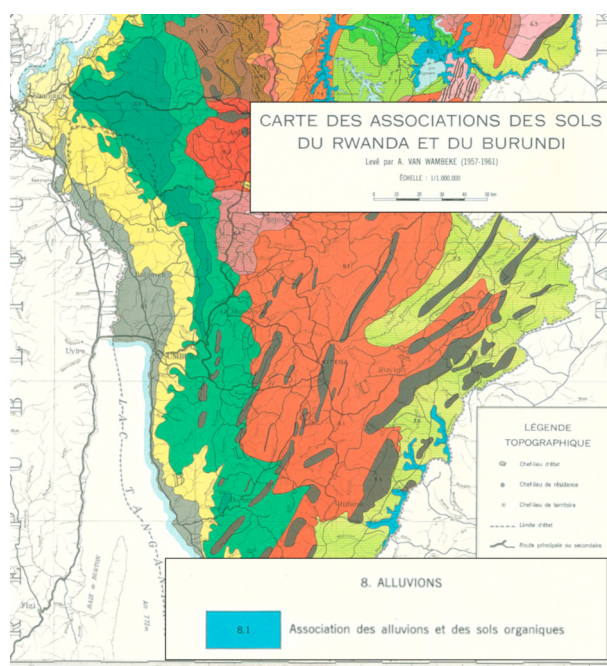
Mosaic of Wetter miombo woodland + riverine wooded vegetation (Wmw/R)

The subzone in the Zambezian domain with riverine forest relicts was split in a part adjacent to the river and the rest. The first was reclassified as riverine woodland (R), the second as mosaic of Wetter miombo woodland + riverine wooded vegetation.

Splitting was done using the vector layer [correction_zone_3.zip](#). Note that areas at altitudes > 1600m were excluded.

```
# Define all areas as mosaic
r.mapcalc "map9 =if(veg_burundi==13 & dem@PERMANENT < 1600, 100, map8)"
--overwrite

# Split area and redefine area along river as riverine woodland
g.region raster=pnv_burundi@BurundiVegetation6v.to.rast
input=CorrectionZone3@BurundiVegetation output=CorrectionZone3 use=val
r.null map=CorrectionZone3 null=0
r.mapcalc "map9 = if(veg_burundi==13 & dem@PERMANENT < 1600, 100, map8)"
--overwrite
r.mapcalc "map9 = if(map9==100 & CorrectionZone3==1, 46, map9)" --overwrite
```



Mosaic of Lake Victoria semi-evergreen thicket + Lake Victoria Euphorbia dawei scrub + riverine wooded vegetation

Subzone in the eastern domain with riverine forest relicts and the Acacia wooded grasslands are assumed to represent the Mosaic of Lake Victoria semi-evergreen thicket + Lake Victoria Euphorbia dawei scrub + riverine wooded vegetation (including forest with no zambezi influence), like at the other side of the border in Rwanda.

Figure 5. Van Wambeke soil map (1975)

```
r.mapcalc "map10 =if(veg_burundi==14 | veg_burundi==1, 1102, map9)"
--overwrite
```

Distribution of swamps (pro parte) and edaphic grasslands

For the mapping of the swamps we used the boundaries from the Van Wambeke soil map (1957; Figure 5). All areas marked as alluvions were classified as g/X compound vegetation type (edaphic grassland / swamp).

```
v.to.rast input=VanWambekeSoil@BurundiVegetation output=VanWambekeSoil
use=val
r.null map=VanWambekeSoil null=-9999
r.mapcalc "map11 = if(mask_pnv_burundi@BurundiVegetation==1 &
VanWambekeSoil==1, 15002, map10)" --overwrite
```

Water bodies

Water bodies were mapped based on the Global Wetland Database (<http://worldwildlife.org/pages/global-lakes-and-wetlands-database>).

```
v.to.rast input=glwd_1@PERMANENT output=glwd use=val --overwrite
r.null map=glwd null=-9999
r.mapcalc "map12 = if(glwd==1 | veg_burundi==15, 50,map11)" --overwrite
```

Correction of unclassified areas

The criteria implemented above leave all areas below 1600m in the zone with Montane forest relicts and the montane forest zone unclassified (Figure 6). As they border the mosaic of Lake Victoria Euphorbia dawei scrub forest and Lake Victoria Strychnos potatorum scrub forest (see below), we added these areas to this mosaic (see code below).

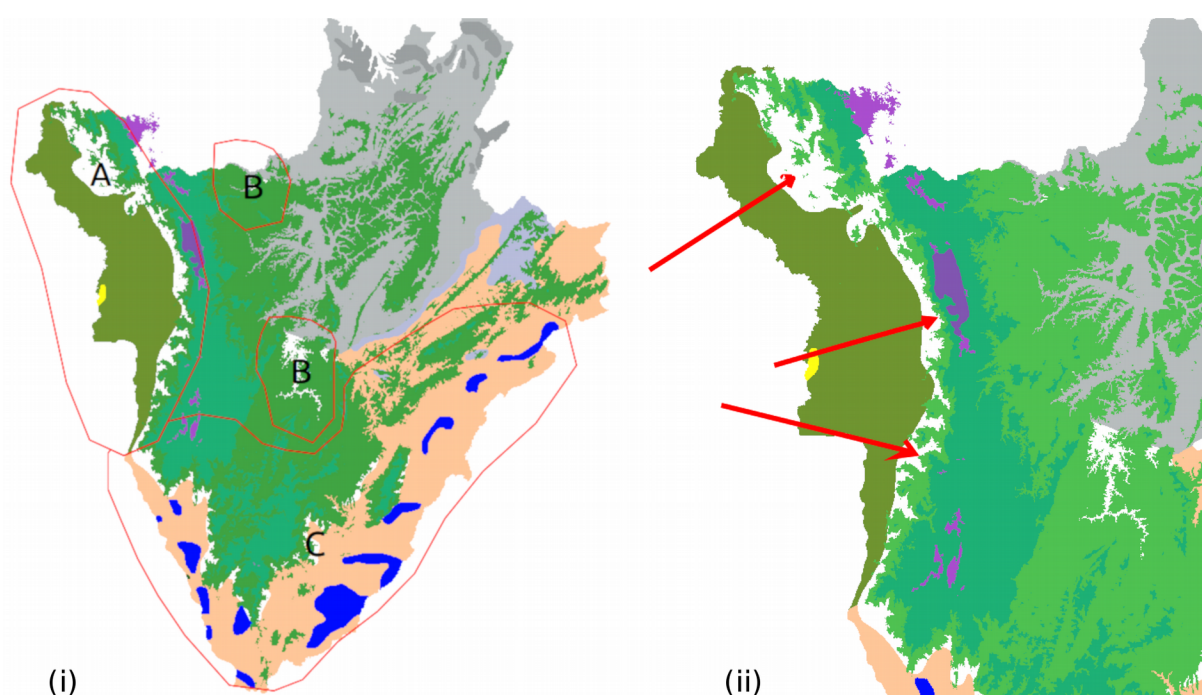
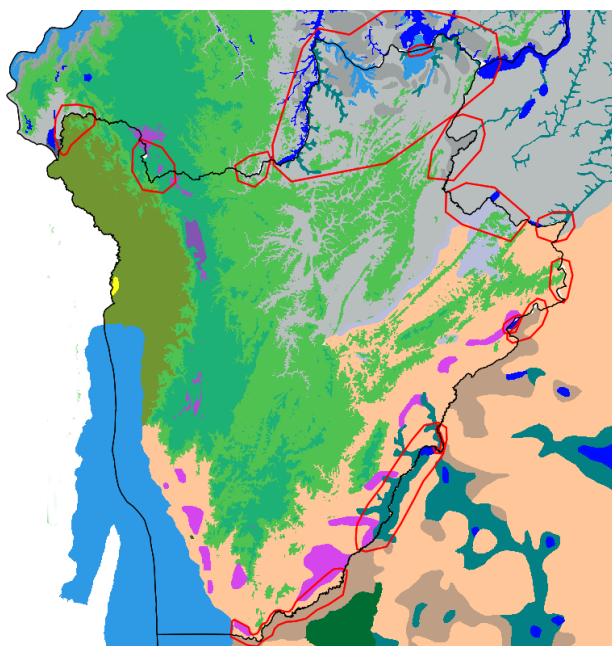


Figure 6. (i) Areas that in Montane forest relicts and the montane forest zone that fall below the 1600m. (ii) Correction zones used to reclassify these areas: A as mosaic of Lake Victoria Euphorbia dawei scrub forest and Lake Victoria Strychnos potatorum scrub forest, B as Mosaic of Evergreen and semi-evergreen bushland and thicket (Be) and upland Acacia wooded grassland (We) and C as Wetter miombo woodland (Wmw)

```
v.to.rast input=correction_zones output=correction_zones use=attr
attrcolumn=Zones
r.null map=correction_zones null=-9999
r.mapcalc "map13 = if(correction_zones==1 & map12== -9999, 97,
if(correction_zones==2 & map12== -9999, 98, if(correction_zones==3 &
map12== -9999, 57, map12)))"
```



There are also a number of areas left unclassified due to a mismatch between the country boundaries of the different data layers. These were corrected by looking at the surrounding PNVs. The code below reclassifies the empty areas within each of the polygons depicted in Figure 7.

Figure 7. Correction zones to correct empty spaces between the regional and Burundi maps due to mismatch in boundary files

```
r.mask -r
v.to.rast input=correction_zones2 output=correction_zones2 use=cat
--overwrite
r.null map=correction_zones2 null=-9999
g.copy pnv_vecea2@vegetation,pnvtemp --overwrite
r.mapcalc "pnvtemp = pnvtemp" --overwrite
r.null map=pnvtemp null=-9999
r.null map=map13 null=-9999
r.mapcalc "map13 = if(map13== -9999 & pnvtemp== -9999 & (dem@PERMANENT>1600 &
dem@PERMANENT<1900), 7, map13)" --overwrite
r.mapcalc "map13 = if(map13== -9999 & pnvtemp== -9999 & correction_zones2==15,
50, map13)" --overwrite
r.mapcalc "map14 = if(map13== -9999 & pnvtemp== -9999 & correction_zones2==2,
15002, map13)" --overwrite
r.mapcalc "map15 = if(map14== -9999 & pnvtemp== -9999 & (correction_zones2==3
| correction_zones2==4 | correction_zones2==5), 98, map14)" --overwrite
r.mapcalc "map16 = if(map15== -9999 & pnvtemp== -9999 & correction_zones2==8,
15002, map15)" --overwrite
r.mapcalc "map17 = if(map16== -9999 & pnvtemp== -9999 & (correction_zones2==10
| correction_zones2==11), 57, map16)" --overwrite
r.mapcalc "map18 = if(map17== -9999 & pnvtemp== -9999 & correction_zones2==12,
41, map17)" --overwrite
r.mapcalc "map19 = if(map18== -9999 & pnvtemp== -9999 & correction_zones2==13,
1, map18)" --overwrite
r.mapcalc "map20 = if(map19== -9999 & pnvtemp== -9999 & correction_zones2==14,
1101, map19)" --overwrite

r.mapcalc "map21 = if(pnvtemp!=41 & correction_zones2==22, 15002, map20)"
--overwrite
r.mapcalc "map22 = if((map21==57 | (map19== -9999 & pnvtemp== -9999)) &
correction_zones2==19, 991, map21)" --overwrite
r.mapcalc "map23 = if(correction_zones2==23 | correction_zones2==24, -9999,
map22)" --overwrite
r.mapcalc "map23 = if(correction_zones2==25 & map23== -9999, 1103, map23)"
r.null map=map23 setnull=-9999
g.rename rast=map23,pnv_burundi
```

Correct location of Miombo (Brachystegia) or lowland Bamboo (Oxytenanthera) wooded grassland areas

Mismatch of polygons with boundaries on Google Earth were corrected using the correction polygons [extra_materials_2.pack](#) and [extra_materials_3.pack](#) (vector layers that can be opened in GRASS GIS using the `r.unpack` function).

```
# Set region and convert vector layer to raster layer

g.region -a vector=CorrectionZones2@BurundiVegetation
r.mapcalc "tmp1 = if(pnv_burundi@BurundiVegetation == 99, 57,
pnv_burundi@BurundiVegetation)"
v.to.rast input=CorrectionZones2@BurundiVegetation output=CorrectionZones2
use=val
r.null map=tmp1 null=0
r.mapcalc "tmp2 = if(tmp1 == 57 && CorrectionZones2==1, 99, tmp1)"

# Correct location of Lake Victoria drier peripheral
# semi-evergreen Guineo-Congolian rain forest (Fi) area

v.to.rast input=tmpforest@BurundiVegetation output=tmpforest use=val
r.null map=tmpforest null=0
r.mapcalc "tmp3 = if(tmp2==57 && tmpforest==1,10,if(tmp2==10,57,tmp2))"

# Patch the layers

g.region raster=pnv_burundi
r.patch --overwrite input=tmp3,pnv_burundi output=pnv_burundi
```

Add categories - Create national map

The map created with the steps above was reclassified using the reclassification table in [legendfile.ods](#). Note that for the regional map, the mapping units numbering was adapted to match that of the regional map.

Correction PNV Rwanda

In Rwanda the vegetation in the southern point bordering Burundi was classified as Evergreen and semi-evergreen bushland and thicket + riverine wooded vegetation (compound) (Be/R) in the PNV map version 1.1. In light of the new evidence about the vegetation just over the border in Burundi, this area was reclassified as mosaic of Lake Victoria Euphorbia dawei scrub forest (fe) and Lake Victoria Strychnos potatorum scrub forest (Ft) (fe/Ft).

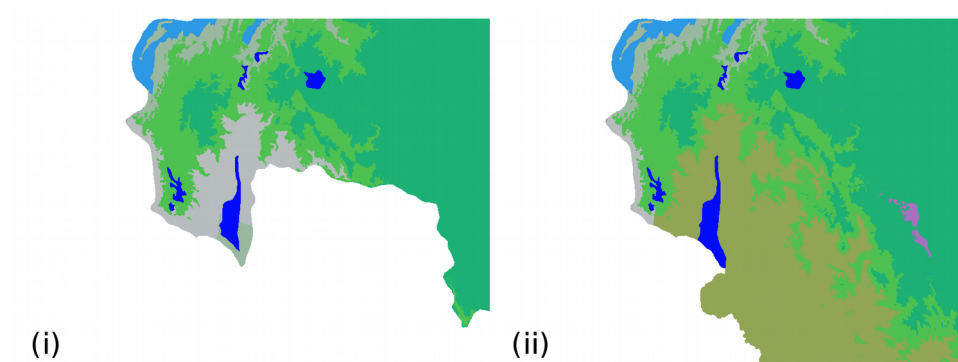


Figure 8. The area in Rwanda and Burundi (ochre) that was classified as a mosaic of Lake Victoria *Euphorbia dawei* Scrub forest and Lake Victoria *Strychnos potatorum* scrub forest.